Chapter 6
Tex-204-F, Design of Bituminous Mixtures

Contents:

Section 1
Overview

Effective Dates: September 2000 to November 2004.

Use this procedure to determine the proper proportions of approved aggregates and asphalt which, when combined, will produce a mixture that will satisfy the specification requirements.

Find typical examples for designs by weight and/or by volume in 'Part I, Typical Example of Design by Weight' and 'Part II, Typical Example of Design by Volume.'

Units of Measurement

The values given in parentheses (if provided) are not considered to be standard and may not be exact mathematical conversions. Each system of units shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

Section 2

Automated Mix Design Report Format

The Mix Design Report is programmed in an automated format using Excel software. The format contains the following files and worksheets.

- Gradation Plot (Power .45 Curve)
- Material Properties
- Combined Gradation
- Weigh-Up Sheet
- Bulk Gravities
- Polish Value Calculations
- Summary
- Asphalt Content vs. Density
- Asphalt Content vs. Voids in Mineral Aggregates
- Asphalt Content vs. Hveem Stability.

Section 3
Procedure

Use the following steps for mixtures of asphalt and aggregate by weight.

Mixtures of Asphalt and Aggregate by Weight

Step	Action
1	♦ Obtain and identify representative samples consisting of a minimum of 23 kg (50 lbs.) of each aggregate to be used. ♦ Sample according to Test Method "Tex-221-F, Sampling Aggregate for Bituminous Mixtures, Surface Treatments and Limestone Rock Asphalt."
2	♦ Obtain and identify an adequate quantity of the asphalt and additives to be used on the project. ♦ Sample according to Test Method "Tex-500-C, Sampling Bituminous Materials, Premolded Joint Fillers, and Joint Sealers."
3	♦ Dry the aggregate to constant weight at a minimum temperature of 38 °C (100 °F). ♦ Dry recycled asphalt pavement (RAP) at a maximum of 60 °C (140 °F).
4	Obtain the average gradation of each proposed aggregate stockpile according to Test Method "Tex-200-F, Sieve Analysis of Fine and Coarse Aggregates." Enter the stockpile gradations on the 'Combined Gradation' worksheet. ♦ Use samples taken from several locations in the stockpile and average the results. When this is not possible, the aggregate samples received in the laboratory may be used for the sieve analysis. ♦ When the specification requires a dry sieve analysis ('Part I, Dry Sieve Analysis [Based on Weight]' of "Tex-200-F, Sieve Analysis of Fine and Coarse Aggregates") it is recommended that a washed sieve analysis ('Part II, Washed Sieve Analysis [When Specified Based on Weight]' of "Tex-200-F, Sieve Analysis of Fine and Coarse Aggregates") be determined for informational purposes. ♦ RAP will be extracted according to Test Method "Tex-210-F, Determining Asphalt Content of Bituminous mixtures by Extraction," before performing a sieve analysis.
5	Check the gradations for compliance with the applicable specification.
6	Check asphalt and additives for compliance with the applicable specifications.
7	When required, determine the 24-hour water absorption and bulk and apparent specific gravities of individual sizes of each aggregate according to test methods "Tex-201-F, Bulk Specific Gravity and Water Absorption of Aggregate," and "Tex-202-F, Apparent Specific Gravity of Material Finer than 180 µm (No. 80) Sieve." Enter gravities on the 'Bulk Gravities' worksheet. ♦ Test lightweight aggregate according to Test Method "Tex-433-A, Apparent Specific Gravity of Material Finer than 180 µm (No. 80) Sieve." Normally, specific gravities are not determined for RAP or aggregate size fractions consisting of less than 15 percent of the individual aggregate. ♦ Smaller aggregate size fractions are assigned the water absorption and specific gravity of the next adjacent size fraction for which values were determined.
8	Combine the aggregates proposed for use in such a manner as to fall within the specified gradation ranges. Consider material availability, mixture strength, handling, compaction, pavement texture, and durability as the primary factors of the combination(s) to be tested.
9	Record stockpile percentages and gradations on the 'Combined Gradation' worksheet.
10	Plot the combined gradation and specification limits on the Power .45 Curve within the Excel program.
11	♦ Check specification compliance of proposed blends of recovered asphalt from RAP and virgin asphalt cement or recycling agents prior to the laboratory mixture preparation stage. ♦ The percentage of recovered asphalt in the blend is based on the percentage of RAP material proposed in the job mix formula and the average extracted asphalt content of the RAP.

Mixtures of Asphalt and Aggregate by Weight	
Step	**Action**
12	♦ Perform Test Method "Tex-203-F, Sand Equivalent Test," on the combined virgin aggregate. ♦ Enter results on the 'Material Properties' worksheet.
13	♦ Check the polish value of the combined aggregates using the 'Polish Value Calculations' worksheet. ♦ Determine whether the percentage of high polish aggregate in the combined blend meets the specification requirements.
14	Separate 2.00 mm (No. 10) aggregate from each stockpile into individual sizes for preparation of laboratory mixtures. ♦ RAP and aggregate passing 2.00 mm (No. 10) can be used without separating into individual sizes if the stockpile gradation is uniformly graded. ♦ If the gradation of the passing 2.00 mm (No. 10) sieve is prone to segregation, it must be separated into individual sizes.
15	Calculate the weights of individual aggregates required to produce batches of mix for each of five asphalt contents. Use the 'Weigh-Up' worksheet in the Excel program.
16	Vary the asphalt contents in 0.5 or 1.0 % increments around the anticipated optimum asphalt content. Enter the asphalt percentages in the AC% column of the 'Summary' worksheet. ♦ A batch size of 5000 g is adequate to produce three molds and one sample for Rice gravity when using a large mechanical mixer. ♦ If hand mixing, the batch size must be the amount needed for one test specimen.
17	Prepare a trial batch according to Test Method "Tex-205-F, Laboratory Method of Mixing Bituminous Mixtures."
18	♦ Select the mixture closest to the estimated optimum asphalt content. ♦ Asphalt additives, which will be pre-blended with the asphalt cement prior to addition at the mixing plant, must be pre-blended into the asphalt cement prior to laboratory mixing.
19	♦ Mold three specimens according to Test Method "Tex-206-F, Compacting Test Specimens of Bituminous Mixtures." ♦ Determine the amount of material necessary to obtain a standard specimen height of 51 ± 1.5 mm (2 ± 0.06 in).
20	♦ After calculating the correct weight to produce the trial specimen of standard height, the total weights for compacted specimens containing other percentages of asphalt can be closely approximated. ♦ Use the corrected weight of the trial specimen as a base value and for every 1% by weight change in asphalt, change the total weight for the specimen by 5 g.
21	Mix and mold four batches determined in Step 20 according to test methods "Tex-205-F, Laboratory Method of Mixing Bituminous Mixtures" and "Tex-206-F, Compacting Test Specimens of Bituminous Mixtures."
22	♦ Determine the theoretical maximum specific gravity (Rice gravity) of three of the mixtures according to Test Method "Tex-227-F, Theoretical Maximum Specific Gravity of Bituminous Mixtures." It is desirable for two of these three mixtures to have asphalt contents above the optimum and one mixture to have an asphalt content below the optimum. ♦ Enter the rice gravities (Gr) in the appropriate column of the 'Summary' worksheet.
23	Treat the mix used to perform this test the same as the mix used for molding. ♦ If + 22.4 mm (+ 7/8 in.) aggregate was removed before molding, remove it from the Rice gravity sample. ♦ If the mix used for molding was cured, cure the Rice gravity sample at the same temperature and for the same length of time.
24	♦ Calculate the effective specific gravity for the combined aggregate at each of the three asphalt

Mixtures of Asphalt and Aggregate by Weight	
Step	**Action**
	contents. ♦ Calculate the average effective specific gravity.
25	Calculate the theoretical maximum specific gravity of the mixture at each asphalt content.
26	♦ Determine the density of the specimens according to Test Method "Tex-207-F, Determining Density of Compacted Bituminous Mixtures." ♦ Enter the bulk gravities (Ga) in the appropriate column of the 'Summary' worksheet.
27	Plot density versus asphalt content using the Excel program. ♦ Determine the optimum asphalt content as the point where the density curve and a line drawn at specification density intersects. ♦ Optimum asphalt content is also determined mathematically by interpolating between data points on the 'Summary' worksheet.
28	♦ Determine the percent stability of the specimens as described in Test Method "Tex-208-F, Test for Stabilometer Value of Bituminous Mixtures." Values may be determined using the Excel program (208-f). ♦ Enter stability values in the appropriate column of the 'Summary' worksheet (204f-r2). ♦ For Coarse Matrix High Binder (CMHB) mixtures, determine the creep properties as described in Test Method "Tex-231-F, Static Creep Test." ♦ Enter creep values in the appropriate column of the 'Summary' worksheet. • Only the specimens at the optimum asphalt content must be tested for creep. • It is also allowable to test the specimens at asphalt contents above and below the optimum and interpolate the creep properties.
29	♦ Plot the stability values (or creep values for CMHB) versus the percent asphalt from the Excel program. ♦ Determine the stability or creep values at optimum asphalt content.
30	If the stability, creep properties, density, or VMA are not within the allowable range, redesign by assuming another combination of aggregates or obtaining different materials.
31	Report data in the format shown under 'Mix Design Report Format'.

Section 4

Part I, Typical Example of Design by Weight

Conditions

The following processed materials have been proposed for use in a hot mix asphaltic concrete mix design.

- Aggregate 'A' is a crushed sandstone with 12.5 mm (1/2 in.) maximum size and polish value of 36
- Aggregate 'B' is a crushed limestone with 6.3 mm (1/4 in.) maximum size and polish value of 30
- Stone screenings
- Field Sand
- AC-20.

Combine the four aggregates and asphalt in proportions that meet the requirements for the applicable hot mix specification, Type D with a polish value requirement of 32.

Solution

The following table describes the process necessary to precisely determine proper mixtures of asphalt and aggregate for a given application or surface requirement where weight is the primary consideration.

Determining Mixtures of Asphalt and Aggregate by Weight

Step	Action
1	Check for specification compliance of all materials.
2	Obtain the sieve analysis of each of the proposed materials as shown in the 'Sieve Analysis Worksheet' table.
3	♦ Consider all factors relating to the production of the available materials and desired mixture properties. ♦ Assume that the best combination of the aggregates will consist of 39% by weight of Aggregate 'A', 23% by weight of Aggregate 'B', 26% by weight of stone screenings and 12% by weight of field sand.
4	Calculate the combined grading as shown in the 'Job-Mix Formula Gradation Worksheet (% Passing)' table.
5	Plot the proposed gradation and master limits on a 0.45 power curve as shown in the 0.45 Power Gradation Chart.
6	Check the proposed aggregate proportioning for compliance with the Polish Value specification using the equations listed under 'Calculations.'
7	Calculate individual aggregate and asphalt weights for the test mixtures as shown in the 'Weigh-Up for 1000 and 5000 Gram Batches at 6% Asphalt' table. ♦ A mixture size of 5000 g is adequate to produce three molds and one sample for Rice gravity when using a large mechanical mixer.

Determining Mixtures of Asphalt and Aggregate by Weight	
Step	**Action**
	♦ If hand mixing, the mixture size must be the amount needed for one test specimen. ♦ The asphalt contents for these test mixes are 4.0, 5.0, 6.0, 7.0 and 8.0% by weight for this mix design example. ♦ Therefore, the corresponding percentages by weight of the aggregate in the mixtures will be 96.0, 95.0, 94.0, 93.0 and 92.0%. ♦ For this example, the total aggregate weight for a 5000 g batch at 6.0% asphalt will be 4700 g and the weight of the asphalt will be 300 g.
8	Mix one of the batches calculated in Step 7 according to Test Method "Tex-205-F, Laboratory Method of Mixing Bituminous Mixtures."
9	♦ Determine the weight of mixture required to produce a specimen height of 51 ± 1.5 mm (2 ± 0.06 in.) by molding a 1000 g sample according to Test Method "Tex-206-F, Compacting Test Specimens of Bituminous Mixtures." ♦ Measure the height of the specimen. ♦ Divide 51 mm (2 in.) by the molded height and multiply by 1000 g to give the corrected weight to produce one 51 mm (2 in.) specimen. ♦ Subtract or add 5 g from this weight for each asphalt content above or below the trial specimen. ♦ For this example, a 1000 g sample with 6.0% asphalt produced a molded specimen with a height of 53.8 mm (2.12 in). ♦ Therefore, the amount of mixture required to produce a 51 mm (2 in.) molded specimen would be 51 mm (2 in.)/53.8 mm (2.12 in.)(1000 g)= 943 g. ♦ The weights for mixes for this example are shown in the 'Ratios of Percent to Weight' table.
10	♦ Weigh the materials for each of the batches containing 4.0, 5.0, 7.0, and 8.0% asphalt. ♦ Mix and mold the test specimens according to test methods "Tex-205-F, Laboratory Method of Mixing Bituminous Mixtures," and "Tex-206-F, Compacting Test Specimens of Bituminous Mixtures." ♦ Mechanical mixing of designs containing Recycled Asphalt Pavement (RAP) is recommended.
11	Determine the theoretical maximum specific gravity (Rice gravity) of three of the mixtures according to Test Method "Tex-227-F, Theoretical Maximum Specific Gravity of Bituminous Mixtures." ♦ It is desirable for two of these three mixtures to have asphalt contents above the optimum and one mixture to have an asphalt content below the optimum. ♦ Treat the mix used to perform this test the same as the samples for molding. ♦ If aggregates retained on the 22.4 mm (7/8 in.) sieve were removed before molding, remove them from the Rice gravity sample. ♦ If the mix used for molding was cured, cure the Rice gravity sample at the same temperature and for the same length of time.
12	Calculate the effective specific gravity for the combined aggregate at each of the three asphalt contents tested for Rice gravity using the equations listed under 'Calculations.'
13	Calculate the theoretical maximum specific gravity of the mixture at each asphalt content using the equations listed under 'Calculations.'
14	Determine the bulk specific gravity of each of the molded specimens according to Test Method "Tex-207-F, Determining Density of Compacted Bituminous Mixtures."
15	Calculate the relative density of each of the molded specimens using the specimen bulk specific gravities (Ga) and the theoretical specific gravities (Gr) in the formula: % Density = 100x Ga/Gr
16	♦ Perform Hveem stability testing on each molded specimen. (Creep testing is not a

Determining Mixtures of Asphalt and Aggregate by Weight	
Step	**Action**
	specification requirement in this example.) ♦ The 'Value Summaries' table summarizes the values from the above tests and calculations for this example.
17	Plot densities on the vertical axis versus asphalt content on the horizontal axis for each set of molded specimens. ♦ Draw a line at the specification optimum density to where it intersects with the density curve. ♦ Draw a vertical line down from this point to where it intersects the horizontal axis to determine the optimum asphalt content. ♦ In this example, the optimum asphalt content is 5.9%. ♦ The optimum asphalt content can also be calculated by interpolating mathematically between the asphalt contents above and below the specified optimum density.
18	Calculate the VMA of the specimens using the equations listed under 'Calculations.'
19	Plot stabilities and VMA versus percent asphalt content. For this example, the stability at optimum asphalt content is 43.
20	Report the mix design on the form shown under 'Mix Design Report Format.'

The following table indicates example weights for mixes.

Ratios of Percent to Weight	
Asphalt Content, %	**Specimen Weight, g**
4.0	933
5.0	938
6.0	943
7.0	948
8.0	953

The following table summarizes example values for gravities, density, and Hveem stability testing.

Value Summaries						
AC, %	**Ga**	**Gr**	**Ge**	**Gt**	**Density, %**	**Hveem Stability %**
4.0	2.241			2.451	91.4	44
5.0	2.262	2.415	2.602	2.416	93.6	45
6.0	2.292	2.380	2.601	2.381	96.3	43
7.0	2.312	2.350	2.605	2.348	98.5	38
8.0	2.307			2.316	99.6	25

The following tables and worksheets are to be referenced when conducting Part I of this test method.

- Sieve Analysis Worksheet

Sieve Analysis Worksheet	
Project:	Highway:
County:	Item No.:
	Sieve Size

	12.5 mm (1/2")	9.5 mm (3/8")	4.75 mm (#4)	2.00 mm (#10)	425 µm (#40)	180 µm (#80)	75µm (#200)	-75 µm (-#200)	Total
Aggregate A									
Weight (gr)		38.7	1150.3	96.8	1.3	1.0	0.8	1.1	1291.0
Ind. % Ret.	0	3.0	89.1	7.5	0.1	0.1	0.1	0.1	100.0
Cum. % Ret.	0	3.0	92.1	99.6	99.7	99.8	99.9		
Cum. % Pass.	100.0	97.0	7.9	0.4	0.3	0.2	0.1		
Aggregate B									
Weight (gr)			2.4	1145.9	37.0	12.4	8.1	11.9	1217.7
Ind. % Ret.	0	0	0.2	94.1	3.0	1.0	0.7	1.0	100.0
Cum. % Ret.	0	0	0.2	94.3	97.3	98.3	99.0		
Cum. % Pass.	100.0	100.0	99.8	5.7	2.7	1.7	1.0		
Screenings									
Weight (gr)				194.2	471.1	367.0	144.1	65.6	1242.0
Ind. % Ret.	0	0	0	15.6	37.9	29.6	11.6	5.3	100.0
Cum. % Ret.	0	0	0	15.6	53.5	83.1	94.7		
Cum. % Pass.	100.0	100.0	100.0	84.4	46.5	16.9	5.3		
Sand									
Weight (gr)					480.0	468.1	172.0	74.0	1194.1
Ind. % Ret.			0	0	40.2	39.2	14.4	6.2	100.0
Cum. % Ret.			0	0	40.2	79.4	93.8		
Cum. % Pass.			100.0	100.0	59.8	20.6	6.2		

- Job-Mix Gradation Worksheet (% Passing)

Job-Mix Formula Gradation Worksheet (% Passing)

Project:				Highway:			
County:				Item No.:			
	Sieve Size						
	12.5 mm (1/2")	9.5 mm (3/8")	4.75 mm (#4)	2.00 mm (#10)	425 µm (#40)	180 µm (#80)	75µm (#200)
Aggregate A							
100%	100.0	97.0	7.9	0.4	0.3	0.2	0.1
39%	39.0	37.8	3.1	0.2	0.1	0.1	0.0
Aggregate B							
100%	100.0	100.0	99.8	5.7	2.7	1.7	1.0
23%	23.0	23.0	23.0	1.3	0.6	0.4	0.2
Screenings							
100%	100.0	100.0	100.0	84.4	46.5	16.9	5.3
26%	26.0	26.0	26.0	21.9	12.1	4.4	1.4
Sand							
100%	100.0	100.0	100.0	100.0	59.8	20.6	6.2
12%	12.0	12.0	12.0	12.0	7.2	2.5	0.7
100%							
%							
Comb. Anal.	100.0	98.8	64.1	35.4	20.0	7.4	2.3

Job-Mix Formula Gradation Worksheet (% Passing)							
Project:				Highway:			
County:				Item No.:			
	Sieve Size						
	12.5 mm (1/2")	9.5 mm (3/8")	4.75 mm (#4)	2.00 mm (#10)	425 µm (#40)	180 µm (#80)	75µm (#200)
Spec.	100	85-100	50-70	32-42	11-26	4-14	1-6

- Weigh-up for 1000 and 5000 Gram Batches at 6% Asphalt

Weigh-up for 1000 and 5000 Gram Batches at 6% Asphalt					
Material ID	**% Aggregate**	**% Mix**	**Cumulative %**	**1000 gram Cumulative Weights**	**5000 gram Cumulative Batch Weigh-up**
Aggregate A					
12.5 – 9.5 mm (1/2" - 3/8")	1.2	1.1	1.1	11	55
9.5 – 4.75 mm (3/8"- No. 4)	34.7	32.6	33.7	337	1685
4.75 – 2.00 mm (No. 4 – No. 10)	2.9	2.7	36.4	364	1820
Pass 2.00 mm (Pass No. 10)	0.2	0.2	36.6	366	1830
Aggregate B					
12.5 – 9.5 mm (1/2" - 3/8")					
9.5 – 4.75 mm (3/8"- No. 4)					
4.75 – 2.00 mm (No. 4 – No. 10)	21.7	20.4	57.0	570	2850
Pass 2.00 mm (Pass No. 10)	1.3	1.2	58.2	582	2910
Screenings					
2.00 mm (+ 10)	4.1	3.9	62.1	621	3105
-2.00 mm (- 10)	21.9	20.6	82.7	827	4135
Sand					
-2.00 mm (- 10)	12.0	11.3	94.0	940	4700
Asphalt					
%		6.0	(6.0)	(60)	(300)
TOTAL	100.0	100.0	100.0	1000	5000

Calculations

The following calculations relate to the
'Determining Mixtures of Asphalt and Aggregate by Weight' procedure.

- Check the proposed aggregate proportioning for compliance with the Polish Value specification (refer to step 6).
  - Minimum required Polish value (PV_s) = 32
  - Polish Value of High Polish rock (PV_h) = 36
  - Polish Value of Low Polish rock (PV_L) = 30.

Requirement No. 1

$$\%H = \frac{100(PV_5 - PV_L)}{Pv_h - PV_L} = \frac{100\times(32-30)}{(36-30)} = 33.3\%$$

Where:

- %H = Minimum % volume of high polish aggregate retained on 2.00 mm (No. 10) sieve.

Actual % By Weight Retained on 2.00 mm (No. 10) Sieve	
Material	**% Retained**
Aggregate A	39.0-0.2=38.8
Aggregate B	23.0-1.3=21.7
Screenings	25.0-21.9=4.1

$$Actual\ \%H = \frac{\frac{38.8}{2.552}}{\frac{38.8}{2.552}+\frac{21.7}{2.539}+\frac{4.1}{2.514}} = \frac{15.12}{15.2+8.5+1.6} = \frac{15.2}{25.3} = 0.60\ or\ 60\%$$

Therefore, Requirement No. 1 is met.

Requirement No. 2

Blended aggregate must contain a minimum of 50% by volume of high polish aggregate retained on the 4.75 mm (No. 4) sieve.

Actual % By Weight Retained on 4.75 mm (No. 4) Sieve	
Material	**% Retained**
Aggregate A	39.0 - 3.1 = 35.9
Aggregate B	23.0 - 23.0 = 0

$$\%Volume\ of\ 4.75\ mm\ (No.4)\ from\ High\ Polish\ Rock = \frac{\frac{35.9}{2.552}}{\frac{35.9}{2.552}} = 1.0\ or\ 100\%$$

Therefore, Requirement No. 2 is met.

♦ Calculate the effective specific gravity for the combined aggregate at each of the three asphalt contents tested for Rice gravity. Use the following formula (refer to step 12):

$$Ge = \frac{100 - As}{\frac{100}{Gr} - \frac{As}{Gs}}$$

Where:

- Ge = Effective specific gravity of the combined aggregates
- Gr = Theoretical maximum specific gravity as measured by Test Method "Tex-227-F, Theoretical Maximum Specific Gravity of Bituminous Mixtures," at the asphalt content, As
- Gs = Specific gravity of the asphalt cement, which is 1.020 in this example
- As = Percent by weight of asphalt cement in the sample.

♦ Calculate the theoretical maximum specific gravity of the mixture at each asphalt content by the following formula (refer to step 13):

$$Gt = \frac{100}{\frac{Ag}{Ge} + \frac{As}{Gs}}$$

Where:

- Gt = Calculated theoretical maximum specific gravity of the mixture at asphalt content, As
- Ge = Average effective specific gravity of the combined aggregates based on Test Method "Tex-227-F, Theoretical Maximum Specific Gravity of Bituminous Mixtures" values.
- Gs = Specific gravity of the asphalt cement
- Ag = Percent by weight of aggregate in the mixture
- As = Percent by weight of asphalt cement in the mixture.

♦ Calculate the VMA of the specimens containing 5.0 and 6.0% asphalt cement to the nearest 0.1%. Using the formula found in Test Method "Tex-207-F, Determining Density of Compacted Bituminous Mixtures," these are found to be 15.7% at 5.0% asphalt and 15.5% at 6.0% asphalt. Interpolate mathematically using the following method to determine the VMA at the optimum asphalt content of 5.9% (refer to step 18):

$$VMA\ @\ Opt\ As = \frac{VMA\ @\ High\ As - VMA\ @\ Low\ As}{(As\ High - As\ Low)}(Opt\ As - Low\ As) + VMA\ @\ Low\ As$$

$$VMA\ @\ 5.9\% = \frac{(VMA\ @\ 6.0\% - VMA\ @\ 5.0\%)}{(6.0 - 5.0)}(5.9\% - 5.0\%) + VMA\ @\ 5.0\%$$

$$VMA\ @\ 5.9\% = (15.5 - 15.7)(0.9) + 15.7 = 15.5$$

Section 5

Part II, Typical Example of Design by Volume

Design the job-mix formula aggregate gradation volumetrically if the aggregate stockpile specific gravities vary by 0.300 or more. Volumetric proportioning is always the most correct method. However, when aggregate specific gravities are similar, the error introduced by designing by weight is considered inconsequential.

Conditions

The following processed materials have been proposed for use in a hot mix asphaltic concrete design:

- Aggregate 'A' is a lightweight with 12.5 mm (½ in.) maximum size and a polish value of 36
- Aggregate 'B' is a crushed limestone with 6.3 mm (¼ in.) maximum size and polish value of 30
- Stone screenings
- Field Sand
- AC-20.

NOTE: Combine the four aggregates and asphalt in such proportions as to meet the requirements for Type 'D' hot mix asphaltic concrete under the applicable hot mix specification with a polish value requirement of 32.

Solution

Use the following steps for mixtures of asphalt and aggregate by volume.

Mixtures of Asphalt and Aggregate by Volume

Step	Action
1	Check for specification compliance of all materials.
2	Obtain the sieve analysis of each of the proposed aggregates as shown in the 'Sieve Analysis Worksheet' (No. 2) table.
3	♦ Consider all factors relating to the production of the available materials and desired mixture properties. ♦ Assume that the best combination of the aggregates will consist of 39% of Aggregate 'A', 23% of Aggregate 'B', 26% of stone screening, and 12% of field sand.
4	♦ Determine the bulk and apparent specific gravities for each aggregate size fraction having 15% or more retained. ♦ Calculate the average stockpile bulk gravities and the bulk specific gravity of the combined gradation. • The results are shown in 'Aggregate Specific Gravities from Test Methods Tex-201-F, Tex-202-F, and Tex-433-A.' ♦ The stockpile specific gravities vary by as much as 1.119, which exceeds 0.300. Volumetric

Mixtures of Asphalt and Aggregate by Volume	
Step	**Action**
	considerations are required.
5	♦ Determine the average water absorptions for individual aggregate size fractions having 15% or more retained. ♦ Calculate the average water absorptions for each stockpile and for the combined gradation. The results for this example are found in 'Aggregate Water Absorptions from Test Methods Tex-201-F and Tex-433-A (Lightweight).' ♦ The water absorption for the combined gradation is greater than 2.0% which indicates that this mixture must be held in the oven for two hours prior to compacting specimens.
6	Assume that the differences in the specific gravities of the size fractions within a given stockpile will not have a significant affect on proportioning of actual materials. This allows the use of the average bulk specific gravity for each stockpile in later calculations.
7	♦ Calculate the combined volumetric job-mix formula using the assumption that the specific gravities of the size fractions within a given stockpile will not have a significant affect on the proportioning. ♦ The 'Job-Mix Formula Gradation Worksheet (Volumetric % Passing)' table shows the volumetric combined gradation which results from combining 39% by volume lightweight, 23% by volume Aggregate 'B', 26% by volume screening, and 12% by volume sand. ♦ The resulting combined gradation meets the specification master gradation limits, which are identical for volumetric and weight proportioning.
8	♦ Check the proposed aggregate proportioning for compliance with polish value requirements. ♦ See Step 6 of the 'Determining Mixtures of Asphalt and Aggregate by Weight' procedure.
9	Plot the proposed combined volumetric gradation and specification master limits on a 0.45 power curve.
10	♦ Calculate individual aggregate and asphalt weights for the test mixtures. ♦ Since all of our calculations to this point have been volumetric, they must be converted to weight percentages so that the necessary weights of individual materials can be determined. ♦ The conversion of the stockpile percentages is shown in the 'Stockpile Conversion Percentages' table. ♦ This is the second application of the assumption that the differences in specific gravities of individual size aggregates within a stockpile will not have a significant effect on the proportioning for the combined gradation. ♦ Using the values in the last column of the 'Stockpile Conversion Percentages' table, calculate the weight percentage of each aggregate size fraction (see the example in the 'Job-Mix Formula Gradation Worksheet [Volumetric Converted to Weight])' table.
11	♦ Calculate individual aggregate and asphalt weights for the test mixtures as shown in the 'Weigh-Up for 4000 Gram Batch at 4% Asphalt' table. ♦ The presence of lightweight aggregate in this example means a specimen with a height of 51 mm (2 in.) will weigh less than if all natural aggregate were used. ♦ A mixture size of 4000 g is adequate to produce three molds and one sample for Rice gravity when using a large mechanical mixer. ♦ The asphalt contents for the test mixes chosen are 4.0, 5.0, 6.0, 7.0, and 8.0% by weight. ♦ Therefore, the corresponding percentages by weight of the aggregate in the mixtures will be 96.0, 95.0, 94.0, 93.0, and 92.0%. As can be seen in the 'Weigh-up for 4000 Gram Batch at 4% Asphalt' table, the total aggregate weight for a 4000 g batch at 4.0% asphalt will be 3840 g and the weight of the asphalt will be 160 g.
12	Mix one of the batches calculated in Step 11 according to Test Method "Tex-205-F, Laboratory Method of Mixing Bituminous Mixtures."
13	♦ Determine the weight of mixture required to produce a specimen height of 51 ± 1.5 mm (2 ±

Mixtures of Asphalt and Aggregate by Volume	
Step	**Action**
	.06 in.) by molding a 900 g sample according to Test Method "Tex-206-F, Compacting Test Specimens of Bituminous Mixtures." ♦ Measure the height of the specimen. ♦ Divide 51 mm (2 in.) by the molded height and multiply by 900 g to give the corrected weight to produce one 51 mm (2 in.) specimen. ♦ Subtract or add 5 g from this weight for each 1% asphalt above or below that of the trial specimen. ♦ For this example, a 900 g sample with 4.0% asphalt produced a molded specimen with a height of 55.9 mm (2.20 in.). ♦ Therefore, the amount of mixture required to produce a 51 mm (2 in.) molded specimen would be 51 mm (2 in.)/55.9 mm (2.20 in.)(900 g)= 817 g. ♦ The weights for mixes for this example are shown in the 'Weights for Mixes' table.
14	♦ Weigh up the materials for each of the batches containing 5.0, 6.0, 7.0, and 8.0% asphalt. ♦ Mix and mold the test specimens according to test methods "Tex-205-F, Laboratory Method of Mixing Bituminous Mixtures," and "Tex-206-F, Compacting Test Specimens of Bituminous Mixtures." ♦ Mechanically mix designs containing RAP.
15	♦ Determine the theoretical maximum specific gravity (Rice gravity) of three of the mixtures according to Test Method "Tex-227-F, Theoretical Maximum Specific Gravity of Bituminous Mixtures." ♦ It is desirable for two of the three mixtures to have asphalt contents above the optimum and one mixture to have an asphalt content below the optimum. ♦ When testing mixtures containing lightweight aggregate, perform the dry-back procedure to determine if water absorption has introduced error in the initial Rice gravity result. ♦ Treat the mix used to perform this test the same as the samples for molding. ♦ If aggregates retained on the 22.4 mm (7/8 in.) sieve were removed before molding, remove them from the Rice gravity sample. ♦ If the mix used for molding was cured, cure the Rice gravity sample at the same temperature and for the same length of time.
16	Calculate the effective specific gravity for the combined aggregate at each of the three asphalt contents tested for Rice gravity using the equations listed under 'Calculations.'
17	Calculate the theoretical maximum specific gravity of the mixture at each asphalt content using the equations under 'Calculations.'
18	Determine the bulk specific gravity of each of the molded specimens according to Test Method "Tex-207-F, Determining Density of Compacted Bituminous Mixtures."
19	Calculate the density of each of the molded specimens using the actual specific gravities (Ga) and the theoretical specific gravities (Gt) in the formula: % Density = 100 x Ga / Gt.
20	Perform Hveem stability testing on each molded specimen. (Creep testing is not a specification requirement in this example.)
21	♦ Plot densities on the vertical axis versus asphalt content on the horizontal axis for each set of molded specimens. • Draw a line at the specification optimum density to where it intersects with the density curve. • Draw a vertical line down from this point to where it intersects the horizontal axis to determine the optimum asphalt content. ♦ In this example, the optimum asphalt content is 5.9%. ♦ The optimum asphalt content can also be calculated by interpolating mathematically between the asphalt contents above and below the specified optimum density.

Mixtures of Asphalt and Aggregate by Volume	
Step	**Action**
22	Calculate the VMA of the specimens to the nearest 0.1% using the equations under 'Calculations.'
23	Plot VMA vs. asphalt content and stabilities vs. asphalt content. Stability at optimum asphalt content for this example is 43.
24	Report the mix design in the format shown under 'Mix Design Report Format.'

The following table details the conversion of stockpile percentages.

Stockpile Conversion Percentages – Volume to Weight					
Stockpile	**Stockpile Proportions % by Volume**		**Stockpile Bulk Specific Gravity**	**Weight, g**	**Stockpile Proportions % by Weight**
Lightweight	39.0	X	1.502	= 58.578	27.4
Aggregate 'B'	23.0	X	2.539	= 58.397	27.3
Screenings	26.0	X	2.524	= 65.624	30.6
Sand	12.0	X	2.621	= 31.452	14.7
TOTAL	100.0			214.051	100.0

The following table lists examples of the weights for mixes used to determine specimen height.

Weights for Mixes	
Asphalt Content, %	**Specimen Weight, g (oz.)**
4.0	817 (28.8)
5.0	822 (29.0)
6.0	827 (29.2)
7.0	832 (29.3)
8.0	837 (29.5)

The following tables and worksheets are to be referenced when conducting Part II of this test method.

- Sieve Analysis Worksheet (No. 2)

Sieve Analysis Worksheet (No. 2)									
Project:					Highway:				
County:					Item No.:				
	Sieve Size								
	12.5 mm (1/2")	9.5 mm (3/8")	4.75 mm (#4)	2.00 mm (#10)	425 µm (#40)	180 µm (#80)	75µm (#200)	Pass -75 µm (-#200)	Total
Lightweight									
Weight (gr)		21.2	622.7	71.9	3.3	0.7	0.8	2.3	722.9
Ind. % Ret.	0	2.9	86.2	9.9	0.5	0.1	0.1	0.3	100.0
Cum. % Ret.	0	2.9	89.1	99.0	99.5	99.6	99.7		
Cum. % Pass.	100.0	97.1	10.9	1.0	0.5	0.4	0.3		

Sieve Analysis Worksheet (No. 2)									
Project:				Highway:					
County:				Item No.:					
	Sieve Size								
	12.5 mm (1/2")	9.5 mm (3/8")	4.75 mm (#4)	2.00 mm (#10)	425 µm (#40)	180 µm (#80)	75µm (#200)	Pass -75 µm (-#200)	Total
Aggregate B									
Weight (gr)	---	---	2.4	1145.9	37.0	12.4	8.1	11.9	1217.7
Ind. % Ret.	0	0	0.2	94.1	3.0	1.0	0.7	1.0	100.0
Cum. % Ret.	0	0	0.2	94.3	97.3	98.3	99.0		
Cum. % Pass.	100.0	100.0	99.8	5.7	2.7	1.7	1.0		
Screenings									
Weight (gr)				194.2	471.1	367.0	144.1	65.6	1242.0
Ind. % Ret.	0	0	0	15.6	37.9	29.6	11.6	5.3	100.0
Cum. % Ret.	0	0	0	15.6	53.5	83.1	94.7		
Cum. % Pass.	100.0	100.0	100.0	84.4	46.5	16.9	5.3		
Sand									
Weight (gr)					480.0	468.1	172.0	74.0	1194.1
Ind. % Ret.			0	0	40.2	39.2	14.4	6.2	100.0
Cum. % Ret.			0	0	40.2	79.4	93.8		
Cum. % Pass.			100.0	100.0	59.8	20.6	6.2		

- Aggregate Specific Gravities from Test Methods Tex-201-F, Tex-202-F, and Tex-433-A)
- Aggregate Water Absorptions From Test Methods Tex-201-F and Tex-433-A (Lightweight)
- Job-Mix Formula Gradation Worksheet (Volumetric % Passing)

Job-Mix Formula Gradation Worksheet (Volumetric % Passing)							
Project:				Highway:			
County:				Item No.:			
	Sieve Size						
	12.5 mm (1/2")	9.5 mm (3/8")	4.75 mm (#4)	2.00 mm (#10)	425 µm (#40)	180 µm (#80)	75µm (#200)
Lightweight							
100%	100.0	97.0	7.9	0.4	0.3	0.2	0.1
39%	39.0	37.8	3.1	0.2	0.1	0.1	0.0
Aggregate B							
100%	100.0	100.0	99.8	5.7	2.7	1.7	1.0
23%	23.0	23.0	23.0	1.3	0.6	0.4	0.2
Screenings							
100%	100.0	100.0	100.0	84.4	46.5	16.9	5.3
26%	26.0	26.0	26.0	21.9	12.1	4.4	1.4
Sand							

Job-Mix Formula Gradation Worksheet (Volumetric % Passing)							
Project:				Highway:			
County:				Item No.:			
	Sieve Size						
	12.5 mm (1/2")	9.5 mm (3/8")	4.75 mm (#4)	2.00 mm (#10)	425 µm (#40)	180 µm (#80)	75µm (#200)
100%	100.0	100.0	100.0	100.0	59.8	20.6	6.2
12%	12.0	12.0	12.0	12.0	7.2	2.5	0.7
100%							
%							
Comb. Anal.	100.0	98.8	64.1	35.4	20.0	7.4	2.3
Spec	100	85-100	50-70	32-42	11-26	4-14	1-6*
* Dry Sieve Analysis							

- Job-Mix Formula Gradation Worksheet (Volumetric Converted to Weight)

Job-Mix Formula Gradation Worksheet (Volumetric Converted to Weight)							
Project:				Highway:			
County:				Item No.:			
	Sieve Size						
	12.5 mm (1/2")	9.5 mm (3/8")	4.75 mm (#4)	2.00 mm (#10)	425 µm (#40)	180 µm (#80)	75µm (#200)
Lightweight							
100%	100.0	97.1	10.9	1.0	0.5	0.4	0.3
27.4%	27.4	26.6	3.0	0.3	0.1	0.1	0.1
Aggregate B							
100%	100.0	100.0	99.8	5.7	2.7	1.7	1.0
27.3%	27.3	27.3	27.2	1.6	0.7	0.5	0.3
Screenings							
100%	100.0	100.0	100.0	84.4	46.5	16.9	5.3
30.6%	30.6	30.6	30.6	25.8	14.2	5.2	1.6
Sand							
100%	100.0	100.0	100.0	100.0	59.8	20.6	6.2
14.7%	14.7	14.7	14.7	14.7	8.8	3.0	0.9
100%							
%							
Comb. Anal.	100.0	99.2	75.5	42.4	23.8	8.8	2.9
Spec.*	100	85-100	50-70	32-42	11-26	4-14	1-6
* Volumetric specification limits are not applicable to converted weight percentages.							

- Weigh-up for 4000 Gram Batch at 4% Asphalt

Weigh-up for 4000 Gram Batch at 4% Asphalt					
Material ID	**% of Aggregate**	**% of Mix**	**Cumulative %**	**1000 gram Cumulative Weights**	**4000 gram Cumulative Batch Weigh-up**
Lightweight					

Weigh-up for 4000 Gram Batch at 4% Asphalt					
Material ID	**% of Aggregate**	**% of Mix**	**Cumulative %**	**1000 gram Cumulative Weights**	**4000 gram Cumulative Batch Weigh-up**
12.5 – 9.5 mm (1/2" - 3/8")	0.8	0.8	0.8	8	32
9.5 – 4.75 mm (3/8"- No. 4)	23.6	22.7	23.5	235	940
4.75 – 2.00 mm (No. 4 – No. 10)	2.7	2.5	26.0	260	1040
Pass 2.00 mm (Pass No. 10)	0.3	0.3	26.3	263	1052
Aggregate B					
12.5 – 9.5 mm (1/2" - 3/8")	0	0			
9.5 – 4.75 mm (3/8"- No. 4)	0.1	0.1	26.4	264	1056
4.75 – 2.00 mm (No. 4 – No. 10)	25.6	24.6	51.0	510	2040
Pass 2.00 mm (Pass No. 10)	1.6	1.5	52.5	525	2100
Screenings					
Plus 2.00 mm (+ 10)	4.8	4.6	57.1	571	2284
Pass 2.00 mm (- 10)	25.8	24.8	81.9	819	3276
Sand					
Pass 2.00 mm (- 10)	14.7	14.1	96.0	960	3840
Asphalt					
%		4.0	(4.0)	(40)	(160)
TOTAL	100.0	100.0	100.0	1000	4000

Calculations

- Calculate the effective specific gravity for the combined aggregate at each of the three asphalt contents tested for Rice gravity. Use the following formula (refer to Step 16):

$$Ge = \frac{100 - As}{\frac{100}{Gr} - \frac{As}{Gs}}$$

Where:

- Ge = Effective specific gravity of the combined aggregates
- Gr = Theoretical maximum specific gravity by Test Method "Tex-227-F, Theoretical Maximum Specific Gravity of Bituminous Mixtures" at the asphalt content, As
- Gs = Specific gravity of the asphalt cement, which is 1.020 in this example

- As = Percent by weight of asphalt cement in the sample.

♦ Calculate the theoretical maximum specific gravity of the mixture at each asphalt content by the following formula (refer to step 17):

$$Gt = \frac{100}{\frac{Ag}{Ge} + \frac{As}{Gs}}$$

Where:

- Gt = Calculated theoretical maximum specific gravity of the mixture at asphalt content, As
- Ge = Average effective specific gravity of the combined aggregates based on Test Method "Tex-227-F, Theoretical Maximum Specific Gravity of Bituminous Mixtures" values
- Gs = Specific gravity of the asphalt cement
- Ag = Percent by weight of aggregate in the mixture
- As = Percent by weight of asphalt cement in the mixture.

Section 6

Part III, Design of Large Stone Mixtures

Use this procedure to determine the proper proportions of approved aggregates and asphalt which, when combined, will produce a mixture that will satisfy the specification requirements.

Procedure

The following table describes the process necessary to determine proper mixtures of asphalt and aggregate for large stone mixtures, i.e. Type-A and Type-B.

Determining Mixtures of Asphalt and Aggregate by Weight

Step	Action
1	Check for specification compliance of all materials.
2	Obtain the sieve analysis of each of the proposed materials as shown in the 'Sieve Analysis Worksheet' in 'Part I, Typical Example of Design by Weight.'
3	♦ Consider all factors relating to production of the available materials and desired mixture properties. ♦ Determine the best combination of the aggregates yielding a gradation within the specification grading limits.
4	Calculate the combined grading as shown in the 'Job-Mix Formula Gradation Worksheet (% Passing)' in 'Part I, Typical Example of Design by Weight.'
5	Plot the proposed gradation and master grading limits on a 0.45 power curve as shown in the 0.45 Power Gradation Chart.
6	If necessary, check the proposed aggregate proportioning for compliance with the Polish Value specification using the equations listed under 'Calculations' of 'Part I, Typical Example of Design by Weight.'
7	Select five different asphalt contents in increments of either 0.5 or 1% where the middle percent is approximately the expected optimum asphalt content.
8	Calculate individual aggregate and asphalt weights for test mixtures at weights of 2000 and 4600 g batches as shown in the 'Weigh-Up for 1000 and 5000 Gram Batches at 6% Asphalt' table in 'Part I, Typical Example of Design by Weight.' ♦ A mixture size of 2000 g is to be used to determine the theoretical maximum specific gravity (Rice gravity) at each asphalt content according to Test Method "Tex-227-F, Theoretical Maximum Specific Gravity of Bituminous Mixtures." Produce one aggregate batch sample at each asphalt content. ♦ A mixture size of 4600 g is adequate to produce one mold when using a large mechanical mixer. Produce two aggregate batch samples at each asphalt content.
9	Mix the batches calculated in Step 8 according to Test Method "Tex-206-F, Laboratory Method of Mixing Bituminous Mixtures." NOTE: Mixed samples for compaction and Rice gravity must be oven cured for 2 hours at the selected compaction temperature.
10	Mold the 4600 g samples mixed in Step 9 according to Test Method "Tex-241-F, Superpave Gyratory Compacting of Test Specimens of Bituminous Mixtures." NOTE: Scalping of material larger than the 22.4 mm (7/8 in.) sieve size is not allowed. ♦ Specimens shall be molded to 100 gyrations at 600 kPa (87 psi). ♦ Specimen height shall be 115 ± 5 mm (4.5 ± 0.2 in.). The mixture size shall be adjusted if

	the specimen height is outside the tolerable range.
11	Determine the Rice gravity for each asphalt content.
12	Calculate the effective specific gravity for the combined aggregate at each of the asphalt contents tested for Rice gravity using the equations listed under 'Calculations' in Part I.
13	Calculate the theoretical maximum specific gravity of the mixture at each asphalt content using the equations listed under 'Calculations' in Part I.
14	Determine the bulk specific gravity of each of the molded specimens according to Test Method "Tex-207-F, Determining Density of Compacted Bituminous Mixtures."
15	Calculate the relative density of each of the molded specimens using the specimen bulk specific gravities (Ga) and the theoretical specific gravities (Gt) in the formula: $\%\ Density = 100\,(Ga\ /\ Gt)$
16	Calculate the voids in the mineral aggregate (VMA) of the specimens using the equations listed under 'Calculations' in Part I.
17	Determine the indirect tensile strength for each molded specimen according to Test Method "Tex-226-F, Indirect Tensile Strength Test."
18	Plot densities on the vertical axis versus asphalt content on the horizontal axis for each set of molded specimens. ♦ Draw a line at the specification optimum density of 97% to where it intersects with the density curve. ♦ Draw a vertical line down from this point to where it intersects the horizontal axis to determine the optimum asphalt content. ♦ The optimum asphalt content can also be calculated by interpolating mathematically between the asphalt contents above and below the specified optimum density.
19	Plot the indirect tensile strength and VMA versus percent asphalt content. Determine the indirect tensile strength and VMA at the optimum asphalt content from Step 18.
20	If the indirect tensile strength, density, or VMA are not within the allowable range, redesign by assuming another combination of aggregates or obtaining different materials. NOTE: Indirect tensile strength must be greater than 690 kPa (100 psi).
21	Report the mix design on the form shown under 'Mix Design Report Format.'

Section 7

Part IV, Superpave Design Procedure

Use this procedure to determine the proper proportions of approved aggregates and asphalt which, when combined, will produce a mixture that will satisfy the specification requirements.

Automated Reports

The following Excel programs/worksheets may be used to determine proper mixtures for Superpave mixtures with nominal maximum aggregate sizes of 12.5 mm, 19.0 mm, 25.0 mm, and 37.5 mm.

- 12.5 mm
- 19.0 mm
- 25.0 mm
- 37.5 mm.

Procedure

The following table describes the process necessary to determine proper mixtures of asphalt and aggregate for Superpave mixtures with a *Nominal Maximum Aggregate Size* of 37.5 mm, 25.0 mm, 19.0 mm, and 12.5 mm. The *Nominal Maximum Aggregate Size* is defined as the sieve size above the first sieve retaining more than 10 percent of the total aggregate mixture.

Determining Mixtures of Asphalt and Aggregate by Weight

Step	Action
1	♦ Obtain and identify representative samples consisting of a minimum of 23 kg (50 lbs.) of each aggregate to be used. ♦ Sample according to Test Method "Tex-221-F, Sampling Aggregate for Bituminous Mixtures, Surface Treatments and Limestone Rock Asphalt."
2	♦ Obtain and identify an adequate quantity of the asphalt and additives to be used on the project. ♦ Sample according to Test Method "Tex-500-C, Sampling Bituminous Materials, Premolded Joint Fillers, and Joint Sealers."
3	Dry the aggregate to constant weight at a minimum temperature of 38 ºC (100 ºF). NOTE: Dry recycled asphalt pavement (RAP) at a maximum of 60 ºC (140 ºF).
4	♦ Obtain the average gradation of each proposed aggregate stockpile according to Test Method "Tex-200-F, Sieve Analysis of Fine and Coarse Aggregates." ♦ Enter the stockpile gradations on the 'Combined Gradation' worksheet (refer to 'Automated Reports'). ♦ Use samples taken from several locations in the stockpile and average the results. When this is not possible, the aggregate samples received in the laboratory may be used for the sieve analysis. NOTE: RAP will be extracted according to Test Method "Tex-210-F, Determining Asphalt Content of Bituminous Mixtures by Extraction," before performing a sieve analysis.

5	♦ Check the individual aggregate stockpiles for compliance with the applicable aggregate specifications. ♦ Check the gradations for compliance with the applicable specification. ♦ Check the Coarse Aggregate Angularity (Crushed Face Count), Fine Aggregate Angularity, and Flat & Elongated.
6	Check asphalt and additives for compliance with the applicable specifications.
Determining Design Aggregate Structure	
7	Combine the aggregates to create *three trial blends* for use in such a manner as to fall within the specified gradation ranges. Consider material availability, mixture strength, handling, compaction, pavement texture, and durability as the primary factors of the combinations to be tested. ♦ Designs make use of 3 to 5 stockpiles to produce a combined gradation meeting gradation specifications. ♦ The gradation curves must be three distinct curves. ♦ It is advised that the gradation curves should not pass through the restriction zone.
8	Record stockpile percentages and gradations on the 'Combined Gradation' worksheet (refer to 'Automated Reports').
9	Plot the combined gradation and specification limits on the Power .45 Curve within the Excel program (refer to 'Automated Reports').
10	Separate 2.36 mm (No.8) aggregate from each stockpile into individual sizes for preparation of laboratory mixtures. ♦ RAP and aggregate passing 2.36 mm (No.8) can be used without separating into individual sizes if the stockpile gradation is uniformly graded. ♦ If the gradation of the passing 2.36 mm (No.8) sieve is prone to segregation, it must be separated into individual sizes.
11	♦ *Estimate an initial asphalt content* for use for the three trial blends determined in Step 7. ♦ Use one estimated asphalt content for all three trial blends. ♦ Estimate an initial asphalt content based on previous hot mix asphalt mixtures designed with similar aggregate materials and with the same maximum nominal aggregate size.
12	♦ Calculate the weights of individual aggregates required to produce batches of mix for each trial blend mixture with the estimated asphalt content from Step 11. ♦ Calculate weights for two laboratory molded specimens and one Theoretical Maximum Specific Gravity (Rice Gravity) for each trial blend mixture. Generally, 4500 to 4700 g of aggregate are required to achieve the specified molded specimen height of 115 ± 5 mm (4.5 ± 0.2 in.). NOTE: It may be necessary to produce a trial specimen to achieve this height requirement. 2000 g of aggregate are required for a sample for the Theoretical Maximum Specific Gravity (Rice Gravity).
13	♦ Prepare the asphalt mixtures according to Test Method "Tex-205-F, Laboratory Method of Mixing Bituminous Mixtures." ♦ Determine the mixing and compaction temperatures from the 'Mixing and Compaction Temperatures' table in Test Method "Tex-241-F, Superpave Gyratory Compacting of Test Specimens of Bituminous Mixtures." ♦ It may be necessary to contact the asphalt binder manufacturer for breakdown and heating temperatures of asphalt binders excessively modified with polymers and additives to achieve the higher temperature performance grades of PG76 and PG82. ♦ Oven-cure the mixtures for compaction and for Rice Gravity for a time period of 2 hours at the selected compaction temperature.
14	♦ Mold two specimens for each trial blend mixture at the design number of gyrations, N(design) according to Test Method "Tex-241-F, Superpave Gyratory Compacting of Test Specimens of

	Bituminous Mixtures." ♦ Determine the number of gyrations at N(initial), N(design), and N(maximum) from the appended chart in the test method.
15	♦ Determine the Theoretical Maximum Specific Gravity (Rice Gravity) for each trial blend mixture according to Test Method "Tex-227-F, Theoretical Maximum Specific Gravity of Bituminous Mixtures." ♦ Enter the Rice gravities (Gr) in the appropriate column of the 'Trial Blend' worksheet (refer to 'Automated Reports').
16	♦ Determine the density of the specimens according to Test Method "Tex-207-F, Determining Density of Compacted Bituminous Mixtures." ♦ Enter the bulk gravities (Ga) in the appropriate column of the 'Trial Blend' worksheet (refer to 'Automated Reports').
17	♦ Calculate the Voids in the Mineral Aggregate (VMA) according to Test Method "Tex-207-F, Determining Density of Compacted Bituminous Mixtures." ♦ Calculate the Voids Filled with Asphalt (VFA). ♦ Calculate the Dust Proportion (DP).
17	Select the trial blend to be used for design that best meets the volumetric mixture criterion.
Determining Design Optimum Asphalt Content (OAC)	
18	♦ Determine the *Design Optimum Asphalt Content* of the mixture using the gradation from the selected trial blend in Step 17. ♦ Evaluate density results of the selected trial blend calculated in step 16. ♦ Choose asphalt contents where the optimum asphalt content is considered to be achieved based upon the density of the selected trail blend. ♦ Vary the asphalt contents in 0.5% increments. Enter the asphalt percentages in the AC% column of the ‘Summary’ worksheet (refer to 'Automated Reports').
19	♦ Calculate the weights of individual aggregates required to produce batches of mix at each chosen asphalt content from Step 18. ♦ Calculate weights for two laboratory-molded specimens and one Theoretical Maximum Specific Gravity (Rice Gravity) for each trial blend mixture. Generally, 4500 to 4700 g of aggregate are required to achieve the specified molded specimen height of 115 ± 5 mm (4.5 ± 0.2 in). NOTE: It may be necessary to produce a trial specimen to achieve this height requirement. 2000 g of aggregate are required for a sample for the Theoretical Maximum Specific Gravity (Rice Gravity).
20	♦ Prepare the asphalt mixtures according to Test Method "Tex-205-F, Laboratory Method of Mixing Bituminous Mixtures." ♦ Use the same mixing and compaction temperatures as those in Step 13. ♦ Oven cure the mixtures for compaction and for Rice Gravity for a time period of 2 hours at the selected compaction temperature.
21	♦ Mold two specimens at each asphalt content at the design number of gyrations, N (design) according to Test Method "Tex-241-F, Superpave Gyratory Compacting of Test Specimens of Bituminous Mixtures." ♦ Determine the number of gyrations at N(initial), N(design), and N(maximum) from the appended chart in the test method.
22	♦ Determine the Theoretical Maximum Specific Gravity (Rice Gravity) at each asphalt content according to Test Method "Tex-227-F, Theoretical Maximum Specific Gravity of Bituminous Mixtures." ♦ Enter the Rice gravities (Gr) in the appropriate column of the 'Summary' worksheet (refer to 'Automated Reports').
23	♦ Calculate the effective specific gravity for the combined aggregate at each asphalt content.

	♦ Calculate the average effective specific gravity.
24	Calculate the theoretical maximum specific gravity of the mixture at each asphalt content.
25	♦ Determine the density of the specimens according to Test Method "Tex-207-F, Determining Density of Compacted Bituminous Mixtures." ♦ Enter the bulk gravities (Ga) at each asphalt content in the appropriate column of the 'Summary' worksheet (refer to 'Automated Reports').
26	♦ Calculate the Voids in the Mineral Aggregate (VMA) according to Test Method "Tex-207-F, Determining Density of Compacted Bituminous Mixtures" at each asphalt content. ♦ Calculate the Voids filled with Asphalt (VFA) at each asphalt content. ♦ Calculate the Dust Proportion (DP) at each asphalt content.
27	♦ Plot densities on the vertical axis versus asphalt content on the horizontal axis for each set of molded specimens. ♦ Draw a line at the specification optimum density of 96% to where it intersects with the density curve. ♦ Draw a vertical line down from this point to where it intersects the horizontal axis to determine the optimum asphalt content. NOTE: Optimum asphalt content can also be calculated by interpolating mathematically between the asphalt contents above and below the specified optimum density on the 'Summary' worksheet (refer to 'Automated Reports').
28	♦ Plot the Voids in the Mineral Aggregate (VMA), Voids filled with Asphalt (VFA), and Dust Proportion (DP) values with asphalt content. ♦ Determine the Voids in the Mineral Aggregate (VMA), Voids filled with Asphalt (VFA), and Dust Proportion (DP) at the optimum asphalt content.
29	If the Voids in the Mineral Aggregate (VMA), Voids filled with Asphalt (VFA), or Dust Proportion (DP) are not within the allowable specification range, redesign by assuming another combination of aggregates or obtaining different materials.
Evaluating Densification of Mixture Design	
30	♦ Calculate the weights of individual aggregates for two laboratory molded specimens and one Theoretical Maximum Specific Gravity (Rice Gravity) with the selected aggregate structure and with the determined optimum asphalt content. ♦ Select the weight of the aggregate batches as the weight used in Step 19.
31	♦ Prepare the asphalt mixtures according to Test Method "Tex-205-F, Laboratory Method of Mixing Bituminous Mixtures." ♦ Use the same mixing and compaction temperatures as those in Step 13. ♦ Oven-cure the mixtures for compaction and Rice Gravity for a time period of 2 hours at the selected compaction temperature.
32	Mold the two specimens at the maximum number of gyrations, N(maximum) according to Test Method "Tex-241-F, Superpave Gyratory Compacting of Test Specimens of Bituminous Mixtures." NOTE: It is important to record and collect the height measured throughout compaction for each molded specimen.
33	♦ Determine the density of the specimens according to Test Method "Tex-207-F, Determining Density of Compacted Bituminous Mixtures." ♦ Enter the bulk gravities (Ga) and Rice Gravity in the appropriate column of the 'Summary' worksheet (refer to 'Automated Reports'). ♦ Enter the height of the molded specimens at the initial number of gyrations, N(initial), design number of gyrations, N(design), and maximum number of gyrations, N(maximum) in the appropriate column of the 'Summary' worksheet (refer to 'Automated Reports').
34	If the calculated density at N(initial), N(design), or N(maximum) are not within the allowable specification range, redesign by assuming another combination of aggregates or obtaining

	different materials. A different aggregate structure may be chosen from the other trial blends initially evaluated in Steps 7-17.
Evaluating Mixture Properties	
35	♦ Calculate the weights of individual aggregates for laboratory molded specimens to be tested for moisture susceptibility according to Test Method "Tex-531-C, Prediction of Moisture Induced Damage to Bituminous Paving Materials Using Molded Specimens" and for rutting according to Test Method "Tex-231-F, Static Creep Test." ♦ Mixture properties are to be evaluated only when the densification criterion has been met from Steps 30-34. ♦ Calculate the weights of individual aggregates for laboratory molded specimens with the optimum asphalt content determined from Steps 18-29 and the design aggregate structure determined from Steps 7-17.
36	♦ Prepare the asphalt mixtures according to Test Method "Tex-205-F, Laboratory Method of Mixing Bituminous Mixtures." ♦ Use the same mixing and compaction temperatures as those in Step 13. ♦ Oven-cure the mixtures for compaction and Rice Gravity for a time period of 2 hours at the selected compaction temperature.
37	♦ Mold the specimens according to Test Method "Tex-206-F, Compacting Test Specimens of Bituminous Mixtures." ♦ Scalping shall be required for mixtures with aggregate greater than 22.4 mm (+ 7/8 in.). ♦ Use the necessary amount of material to obtain a standard specimen height of 51 ± 1.5 mm (2 ± 0.06 in.).
38	Determine the density of the specimens according to Test Method "Tex-207-F, Determining Density of Compacted Bituminous Mixtures."
39	Report the test results in the appropriate column of the 'Test Summary' worksheet (refer to 'Automated Reports').
40	If the calculated test properties from either Test Method "Tex-531-C, Prediction of Moisture Induced Damage to Bituminous Paving Materials Using Molded Specimens" or "Tex-231-F, Static Creep Test" are not within the allowable specification range, redesign by assuming another combination of aggregates or obtaining different materials. A different aggregate structure may be chosen from the other trial blends initially evaluated in Steps 7-17. The use of an anti-stripping additive may be considered if the test properties determined from Test Method "Tex-531-C" are not met.
41	Report data in the format shown under 'Mix Design Report Format' (refer to 'Automated Reports').

12.5 mm (1/2 in.) Superpave Design Example

The following processed materials have been proposed for use in a 12.5 mm (1/2 in.) Superpave mixture design:

- Aggregate 'A' is a coarse crushed limestone 16.0 mm (5/8 in.) stockpile with 12.5 mm (1/2 in.) maximum nominal size.
- Aggregate 'B' is an intermediate crushed limestone Grade 5 stockpile with 4.75 mm (No. 4) maximum nominal size.
- Aggregate 'C' is crushed limestone screenings.

The following example is a 3-bin design.

1. The first part of the Superpave mixture design procedure determines the *Design Aggregate Structure*. The aggregates were combined in such proportions to make *three* Trial Blends where the gradation requirements met all the grading specifications for a 12.5 mm (1/2 in.) Superpave mixture design. Gradations for the Trial Blends were determined when it was found that all the aggregate stockpiles met or exceeded all the required aggregate property specifications. The 'Gradation and Bin Proportions for Three Trial Blends' table lists the stockpile gradations for each stockpile used in this design example also. The table lists the bin percentage of each aggregate stockpile used for each Trial Blend and the combined gradation for each Trial Blend.
2. 'Trial Blend Gradations Curve' is a plot of the gradation curves for each Trial Blend calculated in the 'Gradation and Bin Proportions for Three Trial Blends' table. The gradation curves were determined below the restriction zone. The 3 gradation curves are distinct and slightly different and within the required grading specifications.
3. An initial asphalt content was chosen at 4.5%. Two specimens were molded and 1 Rice gravity mixed for each Trial Blend at the chosen initial asphalt content of 4.5%. The number of gyrations at N(initial), N(design), and N(maximum) and mixing and molding temperatures were determined according to Test Method "Tex-241-F, Superpave Gyratory Compacting of Test Specimens of Bituminous Mixtures."
   - N (initial) – 8: Mixing Temperature – 143 ºC (290 ºF)
   - N (design) – 100: Molding Temperature – 121 ºC (250 ºF)
   - N (maximum) – 160.

Gradation and Bin Proportions for Three Trial Blends

Gradation and Bin Proportions for Three Trial Blends							
Sieve Size		**Aggregate**	**Aggregate**	**Screenings**	**Trial Blend**		
mm	**in.**	**'A'**	**'B'**		**1**	**2**	**3**
		Stockpile Gradation			**Combined Gradation**		
19.0	3/4	100.0	100.0	100.0	100.0	100.0	100.0
12.5	1/2	25.4	100.0	100.0	90.3	90.3	90.3
9.5	3/8	1.3	97.6	100.0	85.9	86.1	86.3
4.75	No. 4	1.0	39.0	100.0	53.6	59.0	63.3
2.36	No. 8	0.8	5.0	79.0	28.2	34.8	40.0
1.18	No. 16	0.7	2.1	50.6	17.5	21.8	25.2
0.600	No. 30	0.7	1.7	33.4	11.7	14.6	16.8
0.300	No. 50	0.6	1.5	21.6	7.8	9.7	11.1
0.150	No. 100	0.4	1.4	13.3	5.2	6.2	7.0
0.075	No. 200	0.2	1.2	8.0	3.3	3.9	4.3
		Bin Percentages					
Trial Blend 1		13%	55%	32%			
Trial Blend 2		13%	46%	41%			
Trial Blend 3		13%	39%	48%			

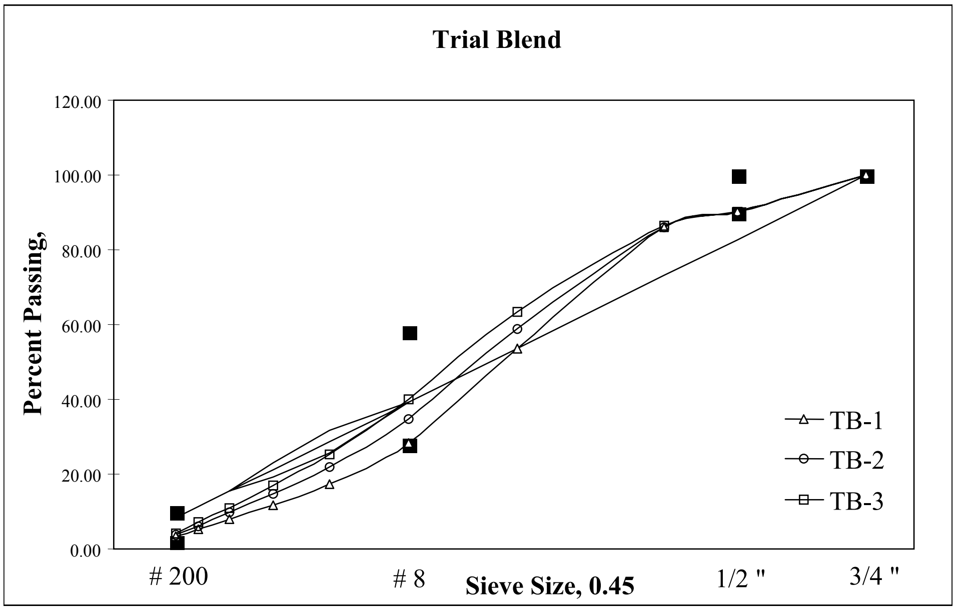

Figure 6-1. Trial Blend Gradation Curves.

'Properties of the Mix and Molded Specimens for each Trial Blend' is a list of the average properties for the molded specimens and Rice gravity of each Trial Blend.

Properties of the Mix and Molded Specimens for each Trial Blend

Properties of the Mix and Molded Specimens for Each Trial Blend			
Property	**Trial Blend**		
	1	**2**	**3**
Specimen Height	113.0 mm (4.41 in.)	113.9 mm (4.48 in.)	114.6 mm (4.51 in.)
Asphalt Content, %	4.5	4.5	4.5
Ga	2.314	2.353	2.376
Gr	2.490	2.480	2.477
Density, %	92.9	94.9	95.9
Specific Gravity of Asphalt	1.02	1.02	1.02
VMA, %	17.3	15.5	14.6
VFA, %	59.0	67.1	71.9
DP	0.7	0.9	1.0

4. The aggregate gradation from Trial Blend 1 was chosen as the *Design Aggregate Structure* for this mixture design example according to results and properties listed in the 'Properties of the Mix and Molded Specimens for each Trial Blend' table. This Trial Blend was chosen because it exceeded the VMA requirement and was within tolerance of the DP specification. The mixture did not meet the VFA specification because of the high VMA and high density. It is desired to select the mixture with the highest VMA such that there is adequate void space for asphalt to achieve the targeted density and meet all the volumetric specifications. This will provide the ideal aggregate gradation for design and production. VFA will increase and meet the specification when determining the optimum asphalt content of the mixture. It is important to note that the use of Trial Blends is only to select an aggregate gradation and not to achieve the targeted density.

5. The *Design Aggregate Structure* has been selected and next the *Design Optimum Asphalt Content* needs to be determined. The density of the specimens from Trial Blend 1 were an average of 92.9 percent. Therefore, additional asphalt is needed to achieve the targeted 96 percent density. Asphalt contents of 5.0 and 5.5 percent were chosen. Two specimens and a Rice gravity were mixed and molded at each selected asphalt content. The 'Volumetric Properties of Specimens Molded to Determine the Design Optimum Asphalt Content' table lists the calculated volumetric properties of the molded specimens and Rice gravity for each asphalt content.

Volumetric Properties of Specimens Molded to Determine the Design Optimum Asphalt Content

Volumetric Properties of Specimens Molded to Determine the Design Optimum Asphalt Content								
Asphalt Content %	**Ga**	**Gr**	**Effective Gravity Ge**	**Theoretical Gravity Gt**	**Density from Gt**	**VMA %**	**VFA %**	**DP**
4.5	2.314	2.490	2.671	2.476	93.5	16.7	61.0	0.7
5.0	2.345	2.454	2.650	2.450	95.7	15.8	72.8	0.7
5.5	2.379	2.429	2.641	2.429	97.9	14.9	86.2	0.6
Interpolated Optimum Mixture Properties @ 96% Density								
			Specification					
Asphalt Content, %		5.1%	N/A					
Voids in the Mineral Aggregate, %		15.7%	15.0% minimum					
Voids Filled with Asphalt, %		74.6%	71 – 80%					
Dust/Asphalt Ratio		0.7%	0.6 – 1.6					

Density at N(initial), N(design) and N(maximum) for Mixture Design with Optimum Asphalt Content

Density		
Number of Gyrations	**Density**	**Specification**
N(initial) – 8	84.8%	89.0% maximum
N(design) – 100	96.4%	96.0 ± 1%
N(maximum) – 160	97.7%	98.0% maximum

6. The *Design Optimum Asphalt Content* and volumetric properties were interpolated at 96 percent density. All the properties met the required specifications for VMA, VFA and Dust/Asphalt Ratio. 'Density of Molded Specimens for the Optimum Asphalt Content, VMA at the Design Optimum Asphalt Content,' and 'VFA at the Design Optimum Asphalt Content' show the density, VMA and VFA with respect to asphalt content.

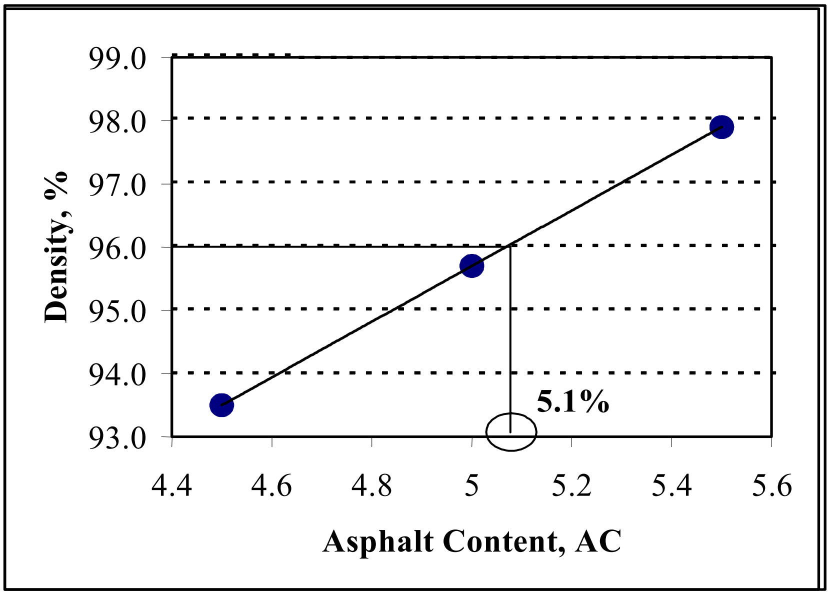

Figure 6-2. Density of Molded Specimens for the Optimum Asphalt Content.

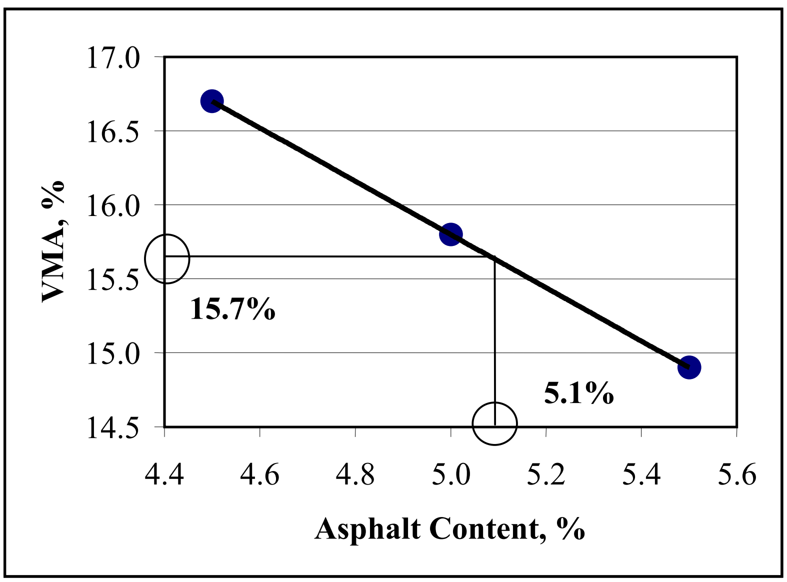

Figure 6-3. VMA at the Design Optimum Asphalt Content.

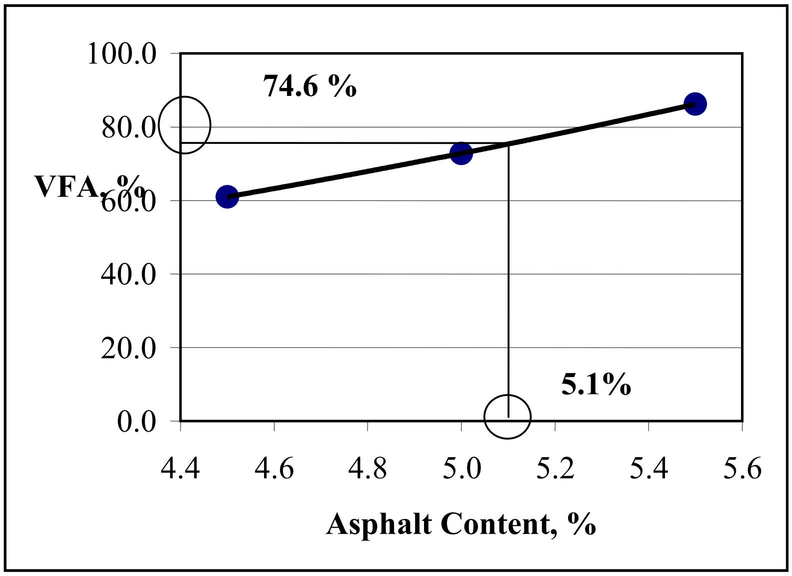

Figure 6-4. VFA at the Design Optimum Asphalt Content.

7. Two specimens were molded and 1 Rice gravity was mixed at the *Design Optimum Asphalt Content* and *Aggregate Structure* to evaluate the *Densification of the Mixture Design.* Specimens were molded to N(maximum) of 160 gyrations. The height of the specimen was recorded throughout compaction. The density of the specimens were determined and recorded as the density at N(maximum). The density was back-calculated at N(initial) and N(design) using the heights recorded at the specified number of gyrations. The 'Density' table lists the densities measured and back-calculated with the required specifications.

8. Specimens were molded with the Texas Gyratory Compactor and tested for moisture susceptibility and rutting. The density of the specimens was recorded before testing. The 'Mixture Properties of the Design' table lists test results with specifications. The mixture design met all the required specifications and considered complete. Record the bin percentages for each aggregate stockpile, combined gradation, OAC with all the other volumetric properties.

Mixture Properties of the Design

Mixture Properties of the Design		
	Laboratory Test Results	**Specification**
Moisture Susceptibility, "Tex-531-C, Prediction of Moisture Induced Damage to Bituminous Paving Materials Using Molded Specimens"		
Conditioned Strength	667.4 kPa (96.8 psi)	483 kPa (70 psi) minimum
TSR	92%	80% minimum
Rutting Susceptibility, "Tex-231-F, Static Creep Test"		
Creep Stiffness	65,213 kPa (9,458 psi)	41,370 kPa (6,000 psi) minimum

Section 8

Archived Versions

Archived versions of Test Method "Tex-204-F, Design of Bituminous Mixtures" are available through the following links:

- Click on 204-0899 for the test procedure effective August 1999 through August 2000.